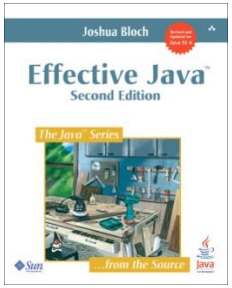
The Lowdown on Lidar

Joshua Bloch

josh@bloch.us

Who am I?

- Software engineer with 25 years experience
- Chief Java Architect at Google (2004-2012)
- Distinguished Engineer at Sun (1996-2004)
- Led design of numerous Java platform features
- Author of several books, including bestselling, Jolt Award-winning *Effective Java*
- Ph.D. in CS from CMU, B.S. from Columbia



So what am I doing here?

- Worked my way through Columbia designing firmware for optical measuring instruments
  - But that was 25 years ago; I am not a Lidar expert
- And I have some legal experience
  - Key witness in a high profile federal IP case *Oracle America, Inc. v. Google, Inc., 810 F.Supp.2d 1002 (N.D. Cal. 2011)*
  - But that has nothing to do with this seminar

What am I *really* doing here?

- Last October, I got a Lidar ticket for going 71 MPH in a 55 MPH zone in Pleasanton
- Had reason to believe I wasn't going that fast
- Read ticket carefully, studied the technology
- Concluded that the ticket didn't establish guilt beyond reasonable doubt
- Filed TBD, but found guilty so I went to court
  - Kim Burgess represented me
- Kim invited me here to share what I learned

Outline

I. A brief quiz
II. How Lidar works - an engineer’s perspective
III. How this applies to my ticket
IV. What do the experts say?
V. Conclusion

I. A brief quiz – four simple questions

1. Does Lidar measure speed?

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3. Can Lidar gun target wrong car (in practice)?

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4. Assuming the gun targets the right car, can it report the wrong speed?

   Yes: *sweep effect*

Don’t feel bad if you got wrong answers

So did Sgt. Greg Koran, CA POST-certified Radar and Lidar instructor (Law Officer Magazine, October 27, 2005)

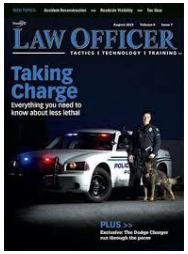
“The lidar unit displays only valid speed readings.”

“You can obtain a speed reading for a specific vehicle as long as you have a direct line of sight.”

“The lidar signal only hits one vehicle, so there’s little doubt which vehicle’s speed the unit displays”

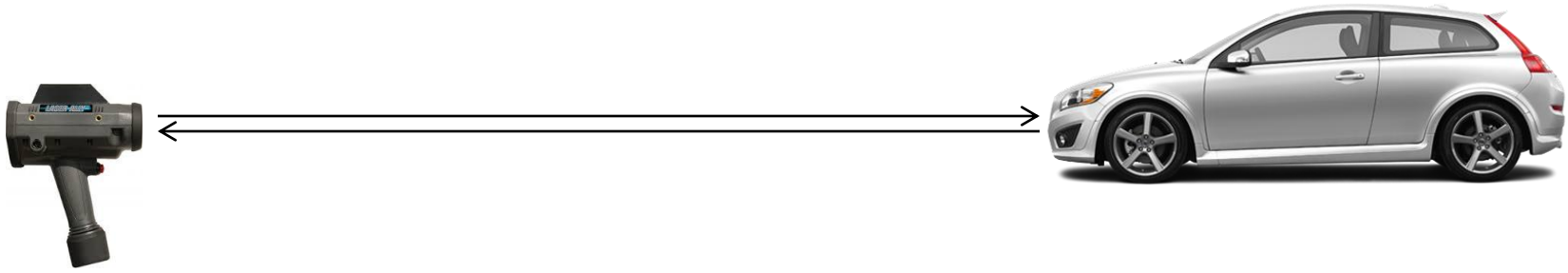
“Lidar units...display the speed of only the vehicle the officer selects.”

“Lidar can instantly give an officer an accurate measurement of objects several thousand ft away.”



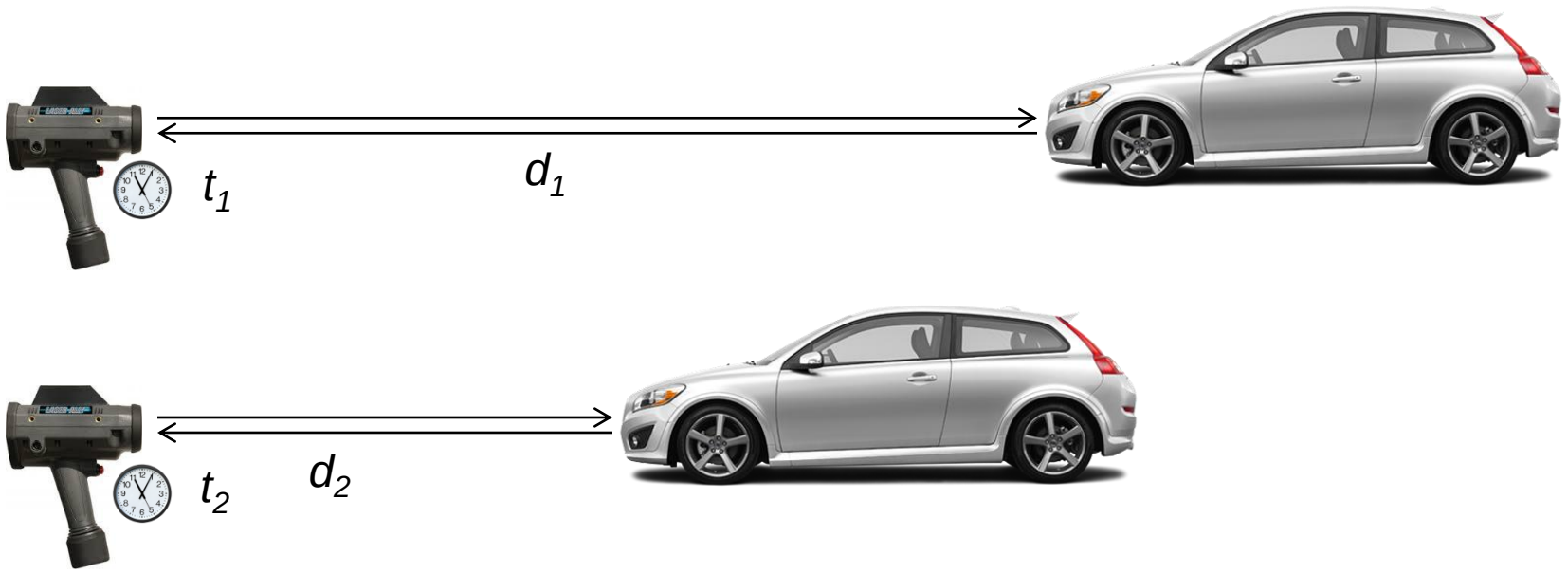
II. How Lidar works, roughly speaking

- Gun emits a pulse of infrared laser light
- Pulse bounces off car and returns to gun
- Gun detects returning pulse and measures its **time**-of-flight (t_f)
- Remember, $speed = \frac{distance}{time}$, so $distance = time \cdot speed$
  - Speed of light is constant ($c \approx 186{,}000$ miles/sec)
  - **Distance** from gun to target $d = \frac{t_f \cdot c}{2}$



How Lidar works, roughly speaking (2)

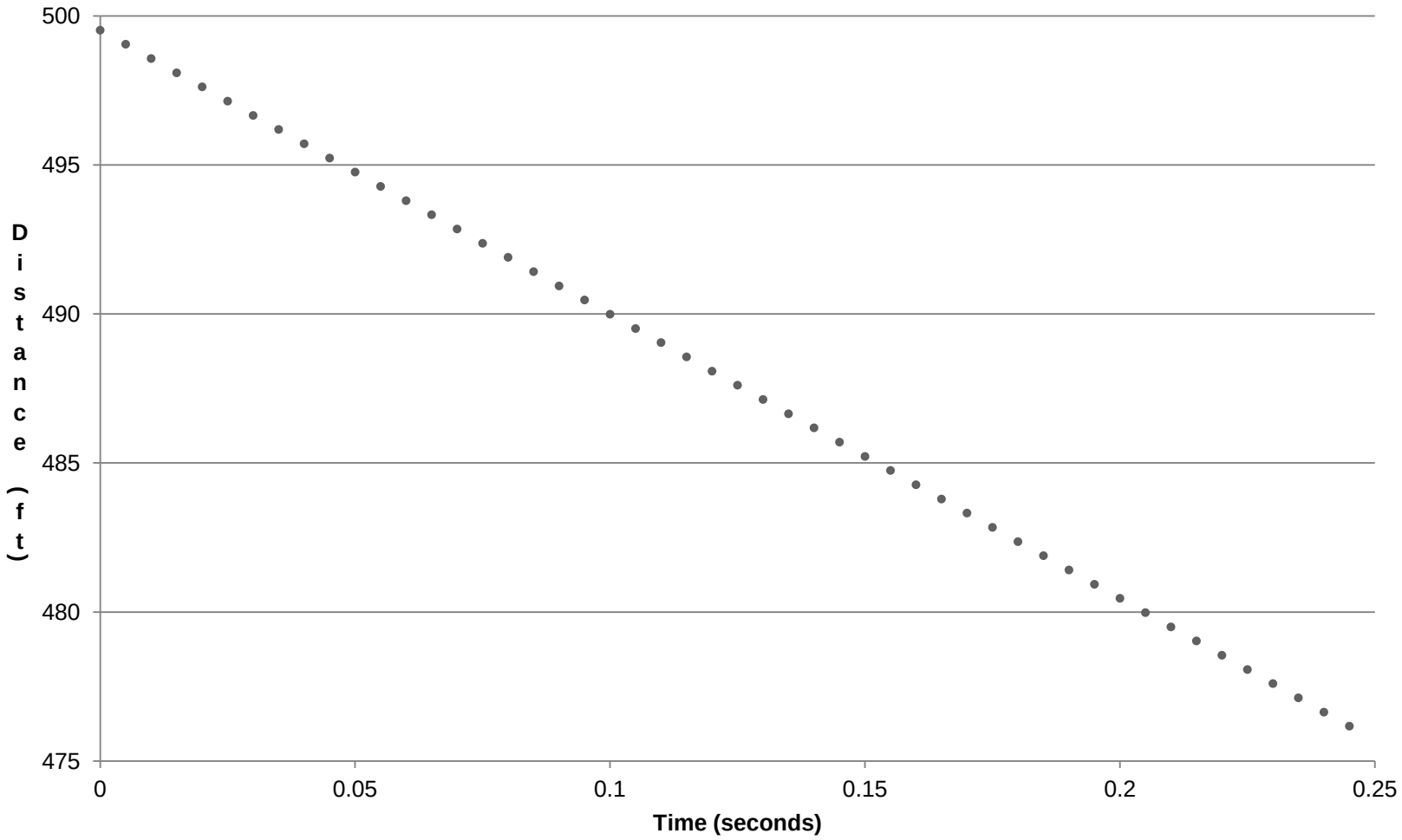
- Then gun waits a while & does it all over again
- Has two *time-distance* pairs, (t_1, d_1) and (t_2, d_2)
- Car moved distance ($d_2 - d_1$) in time ($t_2 - t_1$)
- So car's speed is $\frac{d_2 - d_1}{t_2 - t_1}$



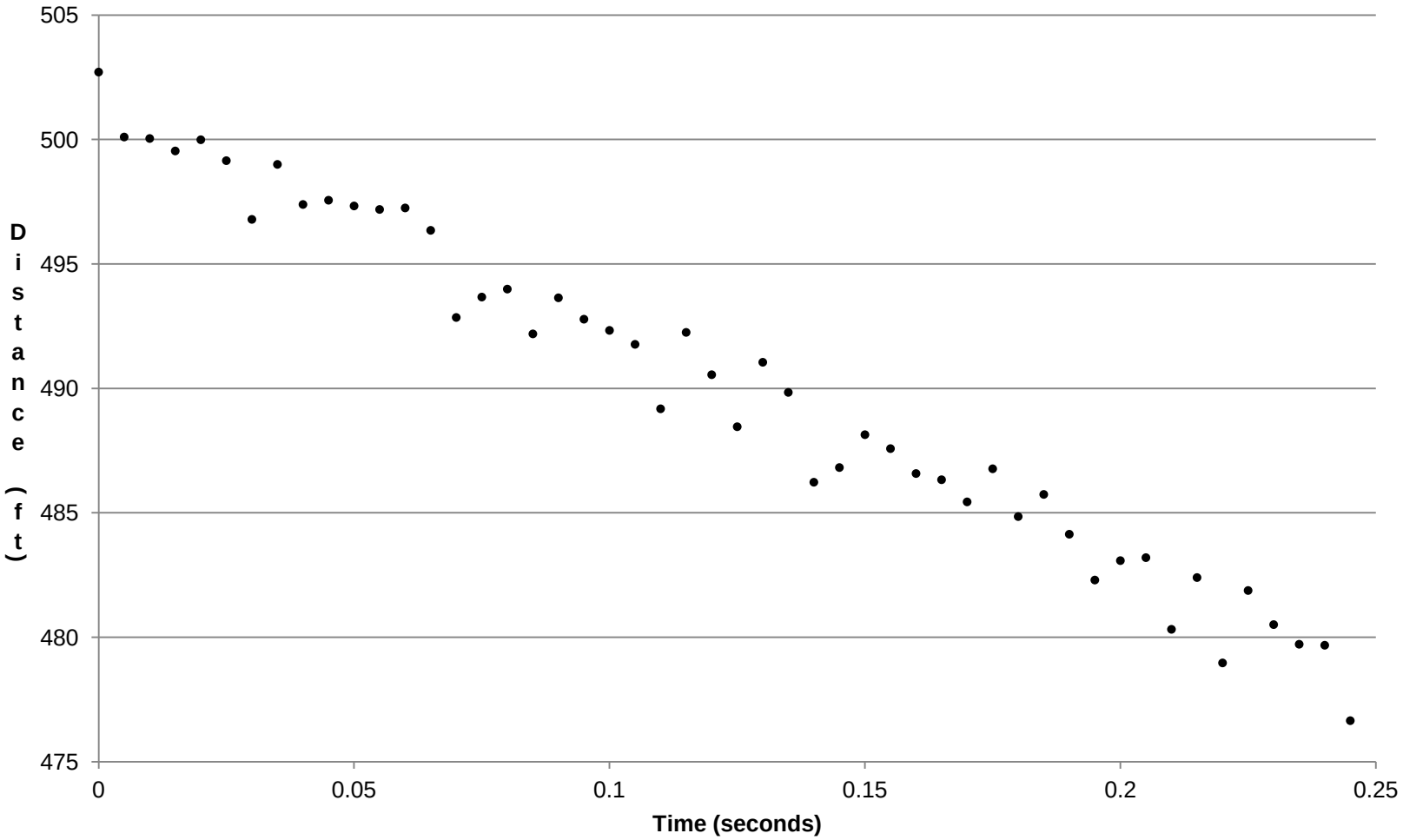
How many measurements does a Lidar gun take, over what time period?

- I don't know
  - It's proprietary, and differs from model to model
- Specifications give *target acquisition time*
  - Upper bound on the measurement period
- Most specifications also give *pulse rate*
  - # measurements < (pulse rate) × (acquisition time)
- Typical target acquisition time: ~ ⅓ second
- Most guns have pulse rates of 125 Hz – 400 Hz
  - TruSpeed S: *variable rate,* **4 KHz** burst, 2.8 KHz avg.

Ideally, raw data would look like this



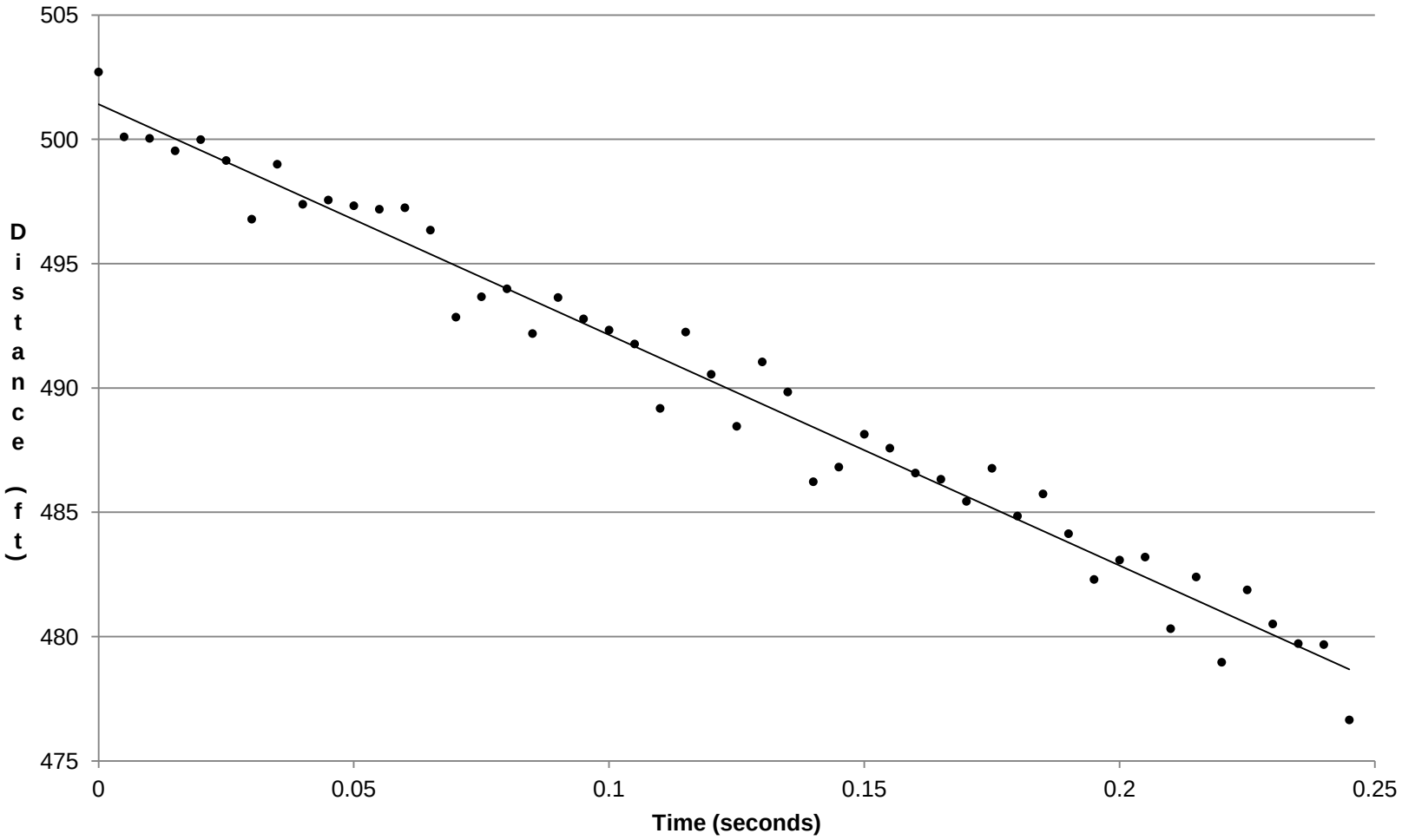
In real life, raw data is noisy



How does Lidar gun cope with raw data?

- I don't know!
  - Algorithm is proprietary; differs from model to model
- Specs and operator manuals provide no clue!
- **Clearly it's some form of statistical analysis**
- The seminal speed Lidar patent (LTI) says this
  - "To enhance the accuracy of speed measurement and compensate for errors due to bad target conditions, poor user operation of the device, and the like, the speed is computed from multiple pairs of measurements. **A highly preferred form of the computation utilizes a least-squares algorithm**."

Speed estimation with least squares

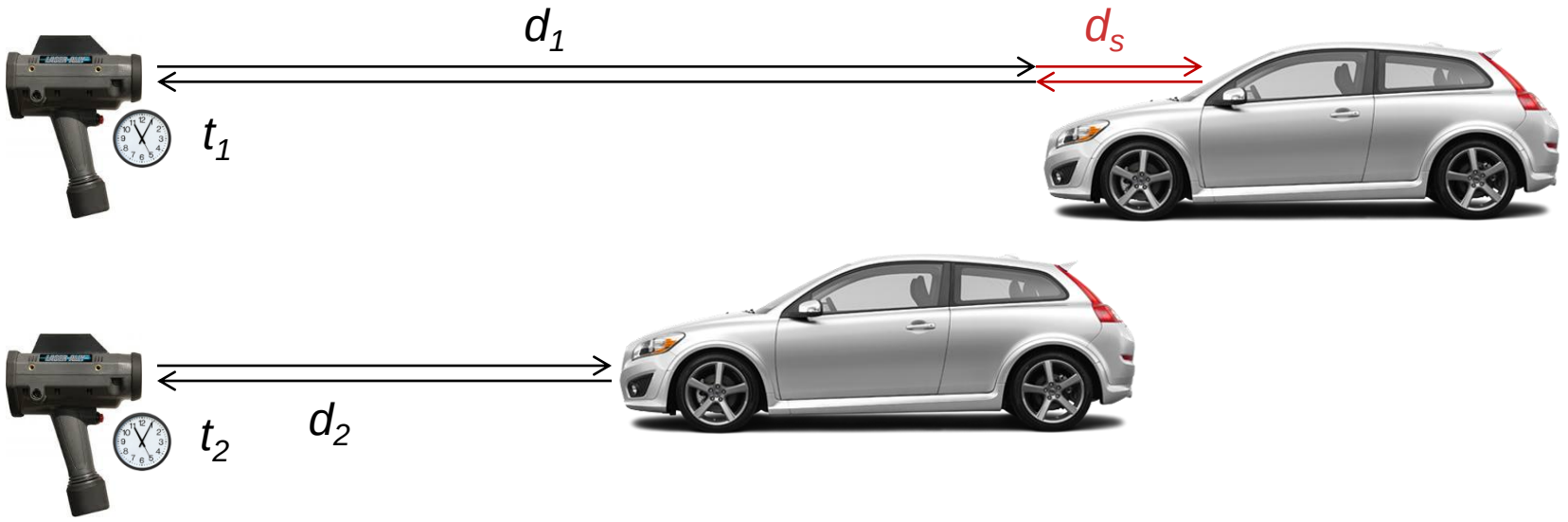


A closer look at distance measurements

- A computation is only as good as its inputs
  - In CS, we say “garbage in, garbage out”
- **Speed computation assumes each distance measurement is to the same point on car**
  - But the Lidar gun can’t know for sure
- Officer can accidentally hit multiple parts of car
  - Gun conflates motion of beam on car w/ car on road
  - Resulting speed “measurement” can be low or high
  - Known as the *sweep effect* (or *slip effect*)

Sweep effect – diagram

- Car's actual speed is $\frac{d_2 - d_1}{t_2 - t_1}$
- But gun measures first distance as $d_1 + d_s$
- So it erroneously reports speed as $\frac{d_2 + d_s - d_1}{t_2 - t_1}$
  - Which is too high by $\frac{d_s}{t_2 - t_1}$



Honest manufacturers admit that their guns are susceptible to the sweep effect

LIDAR LR

HAND HELD POLICE LASER

New Electronics Improve Processing

Internal circuit boards have been combined for speedier processing and easier service. The result is a 284:1 increase in processing power yielding an increase in time and resolution.

Dynamic Range Capabilities

The STALKER LIDAR LR now features an improved tracking algorithm, leading to smoother tracking, fewer dropouts, and a reduced sweep effect.

Single-Shot and Continuous Tracking Modes

The LIDAR LR can be set in Single-Shot mode where the trigger is pressed and the unit locks on a single speed reading. Or, the unit can be operated in tracking mode where the trigger is pressed and the unit takes continuous, real-time speed readings.

Doppler-Type Audio Tracking

Since most laser operators also operate radar, the LIDAR LR generates a continuous Doppler-type audio tone which correlates to the target speed. Just like the audio on a police radar, this audio is a substantial aid to understanding and building a target tracking history - providing a better evidentiary case for citations.

Features include

- Newly Designed Optics
- Updated Electronics
- New ergonomic, rechargeable battery handle provides better balance, which means less physical stress
- Integrated battery charger
- Improved latch-secured handle
- State-of-the-art Surface Mount Technology
- New 32-bit processor compared to the previous 8-bit processor
- New CPU's clock rate is 5X faster for faster target aquisition
- Standardized receiver board built to accommodate future enhancements
- Time Distance Converter (TDC) for improved time/distance measurements
- Doppler Audio Tracking

Specifications

Dimensions:	9.4" Height, 6.8" Length, 4.2" Width (23.9 cm Height, 17.3 cm Length, 10.7 cm Width)
Weight:	Including Battery Handle - 3.9 lbs (1.77 kg)
Housing:	Metal case with rubber end caps
Environmental:	-30° to +60° C, operating -40° to +85° C, non-operating
Humidity Protection:	+37° C, 90% Relative Humidity
Battery Life:	Typically 300 - 330 charge cycles
Battery Charge:	Li-Ion battery: Approx. 2 - 3 shifts (6) AA Alkaline batteries : Approx. 2 shifts (6) AA Rechargeable batteries: Approx. 2 shifts
Type:	Handheld LIDAR offering Tracking mode, Single-Shot mode, and Time/Distance mode.
Acquisition Time:	Less than .4 second
Nominal Range:	Maximum < 5 feet (1.5 m) Normal = 2500 feet (762 m) approaching targets Maximum > 4,000 feet (1200 m)
Range Accuracy:	± .5 feet (.15 meter)
Speed Measure:	2 mph to 299 mph (2 km/h to 481 km/h, 2 knots to 344 knots)
Speed Accuracy:	± 1 mph (± 2 km/h, ± 1 knots)
Time/Dist. trigger mode:	Separate trigger depressions when target enters and exits speed zone.
Remote Trigger:	Remote trigger signal available through I/O Port.
Target Speed Tone:	Variable audio tone corresponding to target speed.
Target Return Tone:	No tone when beam is off target; tone repetition increases as beam moves into target and return signal quality increases.
Switching Output:	I/O Port signal for operation of external devices (e.g. a camera). Toggles when speed exceeds speed signal setting. (special order only)
Operating Wavelength:	905 ± 10 nm Peak @ 25° C
Eye Safety:	FDA/CDRH CLASS 1 Laser Device (Eyesafe)
Power Output:	50 uW maximum average power. (385 nJ maximum pulse energy) (meets FDA/CDRH regulations)
Pulse Width:	< 30 nsec.
Beam Divergence:	< 3 mrad FWHM. 3 feet x 3 feet @ 1000 feet (.9 meters x .9 meters @ 304.8 meters)

Spanish LCD Available

LIDAR LR-EU CE Approved

STALKER® Radar | Lidar

The World Leader in Speed Measurement

ISO 9001:2008

1-800-STALKER

applied concepts, inc.

2609 Technology Drive ■ Plano, Texas 75074

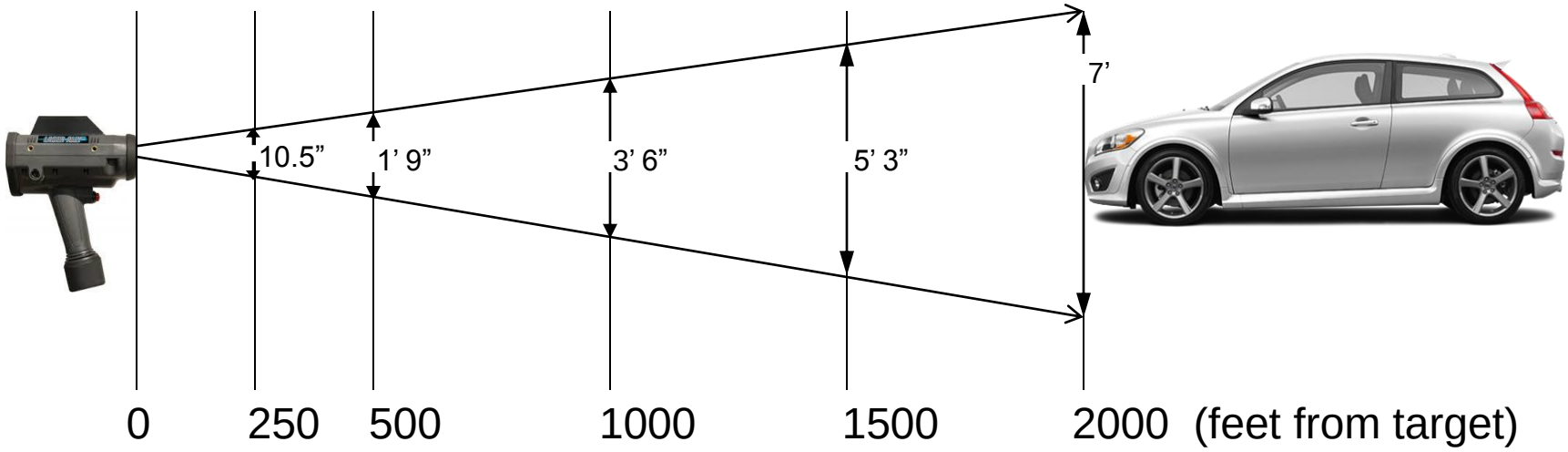
972.398.3780 ■ Fax 972.398.3781

StalkerRadar.com

006-0459-00 Rev D

Beam spread

- Specs for Lidar guns include *beam divergence*
  - Typically 2.5 - 3.5 milliradians (.14° - .20°)
- This yields a simple formula for beam width
  - width = 2 × tan(*divergence* / 2) × *d* = .0035 × *d*



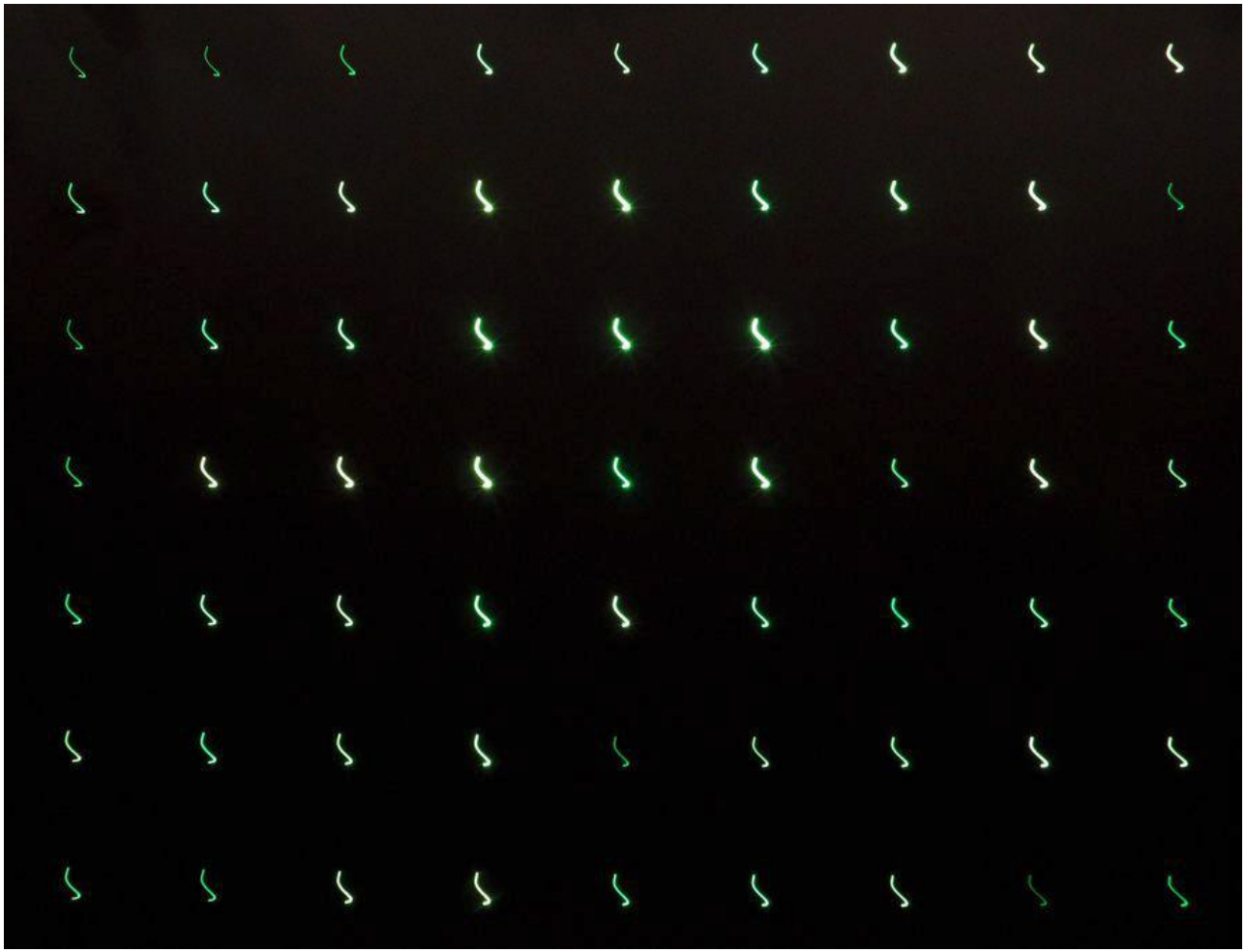
Hand shake

- Officer is tracking moving car with handheld gun
  - Could use tripod, but most officers don't
- Measurement interval is **long** (~ ⅓ s)
- Even if car weren't moving, no one can hold hand perfectly still this long
- Any photographer knows this ("camera shake")
  - Handheld exposure with ⅓ s shutter speed is blurry

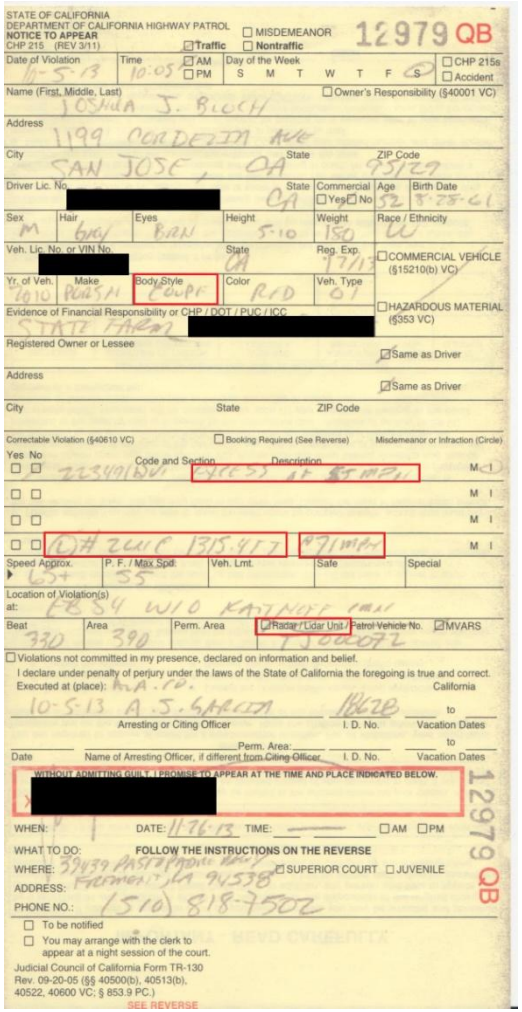
  - The longer the focal distance, the blurrier

Hand shake – a picture is worth 1000 words

Photographer asked to hold DSLR perfectly still (⅓ s.)
Image taken from scholarly paper on camera shake



III. How does all this apply to my ticket?



STATE OF CALIFORNIA
DEPARTMENT OF CALIFORNIA HIGHWAY PATROL
NOTICE TO APPEAR
CHP 215 (REV 3/11)

☐ MISDEMEANOR ☐ Nontraffic
12979 QB

☑ Traffic

Date of Violation: 11-5-13 | Time: 10:05 ☑ AM ☐ PM | Day of the Week: S M T W T F S | ☐ CHP 215s ☐ Accident

Name (First, Middle, Last): JOSHUA J. BLECH ☐ Owner's Responsibility (§40001 VC)

Address: 1199 CORDELIA AVE

City: SAN JOSE, State: CA, ZIP Code: 95129

Driver Lic. No. [redacted] State: CA | Commercial ☐ Yes ☐ No | Age: 32 | Birth Date: 8-28-81

Sex: M | Hair: BRO | Eyes: BRN | Height: 5-10 | Weight: 150 | Race / Ethnicity: W

Veh. Lic. No. or VIN No. [redacted] State: CA | Reg. Exp. 07/13 | ☐ COMMERCIAL VEHICLE (§15210(b) VC)

Yr. of Veh.: 2010 | Make: NISSAN | Body Style: COUPE | Color: RED | Veh. Type: 01 | ☐ HAZARDOUS MATERIAL (§353 VC)

Evidence of Financial Responsibility or CHP / DOT / PUC / ICC: STATE FARM [redacted]

Registered Owner or Lessee ☑ Same as Driver

Address ☑ Same as Driver

City State ZIP Code

Correctable Violation (§40610 VC) ☐ Booking Required (See Reverse) Misdemeanor or Infraction (Circle)

Yes	No	Code and Section	Description	
☐	☐	22349(b)VC	EXCESS SPEED	M I
☐	☐			M I
☐	☐			M I
☐	☐	(D)# 2WLC 1315.4 FT	71 MPH	M I

Speed Approx.: 65+ | P. F. / Max Spd.: 55 | Veh. Lmt. | Safe | Special

Location of Violation(s) at: EB 84 W/O KAISER RMU

Beat: 33D | Area: 39D | Perm. Area | ☑ Radar / Lidar Unit / Patrol Vehicle No. [redacted] ☑ MVARS

☐ Violations not committed in my presence, declared on information and belief.

I declare under penalty of perjury under the laws of the State of California the foregoing is true and correct.
Executed at (place): M.A.PD. California

10-5-13 A.S. GARCIA [redacted] I. D. No. ____ to ____ Vacation Dates
Arresting or Citing Officer

Date ____ Name of Arresting Officer, if different from Citing Officer ____ Perm. Area: ____ I. D. No. ____ to ____ Vacation Dates

WITHOUT ADMITTING GUILT, I PROMISE TO APPEAR AT THE TIME AND PLACE INDICATED BELOW.

[redacted]

12979 QB

WHEN: DATE: 11-26-13 TIME: ____ ☐ AM ☐ PM

WHAT TO DO: FOLLOW THE INSTRUCTIONS ON THE REVERSE

WHERE: 39439 PASTORIA AVE, FREMONT, CA 94538 ☑ SUPERIOR COURT ☐ JUVENILE

ADDRESS:

PHONE NO.: (510) 818-7502

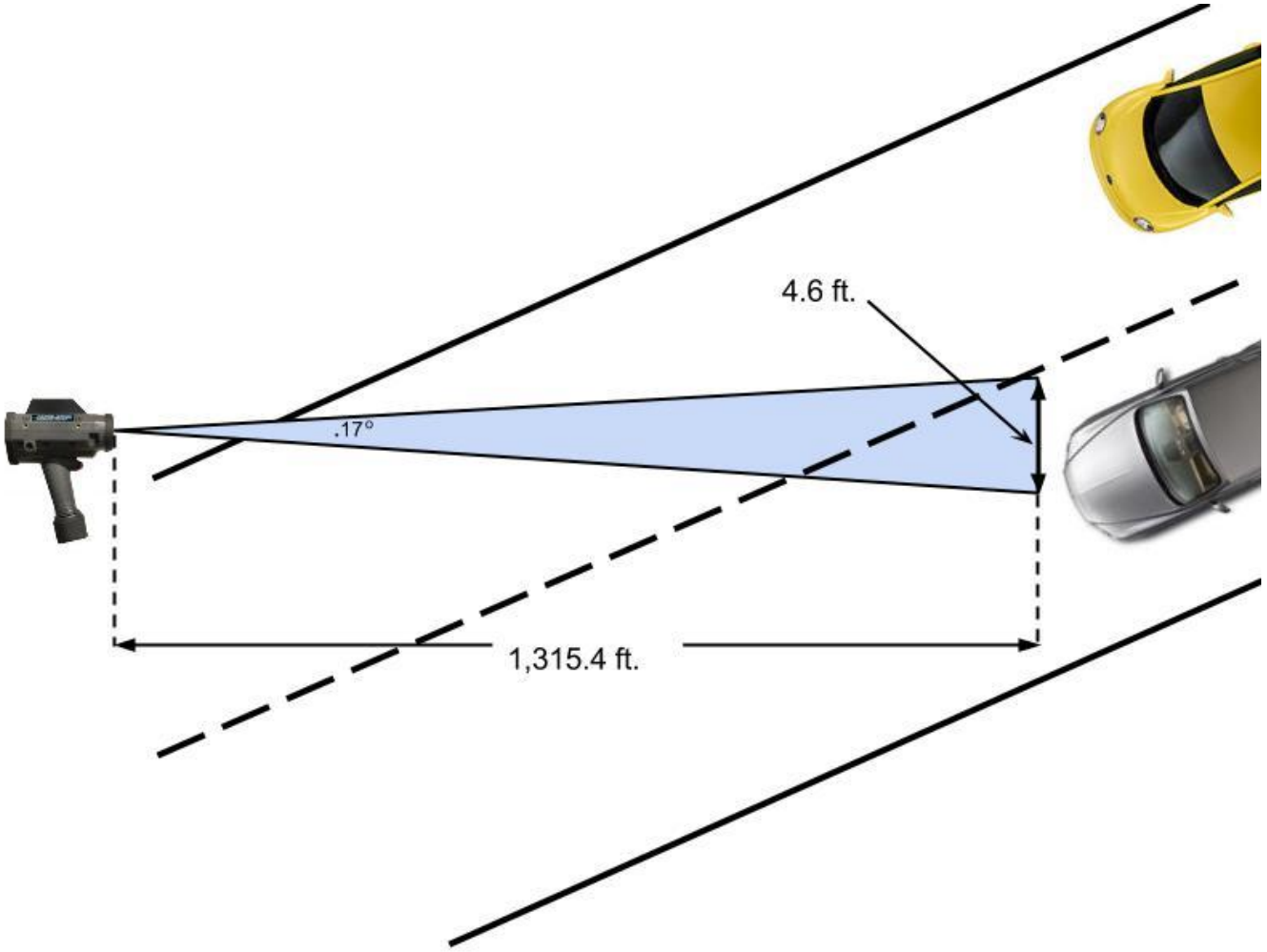
☐ To be notified
☐ You may arrange with the clerk to appear at a night session of the court.

Judicial Council of California Form TR-130
Rev. 09-20-05 (§§ 40500(b), 40513(b), 40522, 40600 VC; § 853.9 PC.)

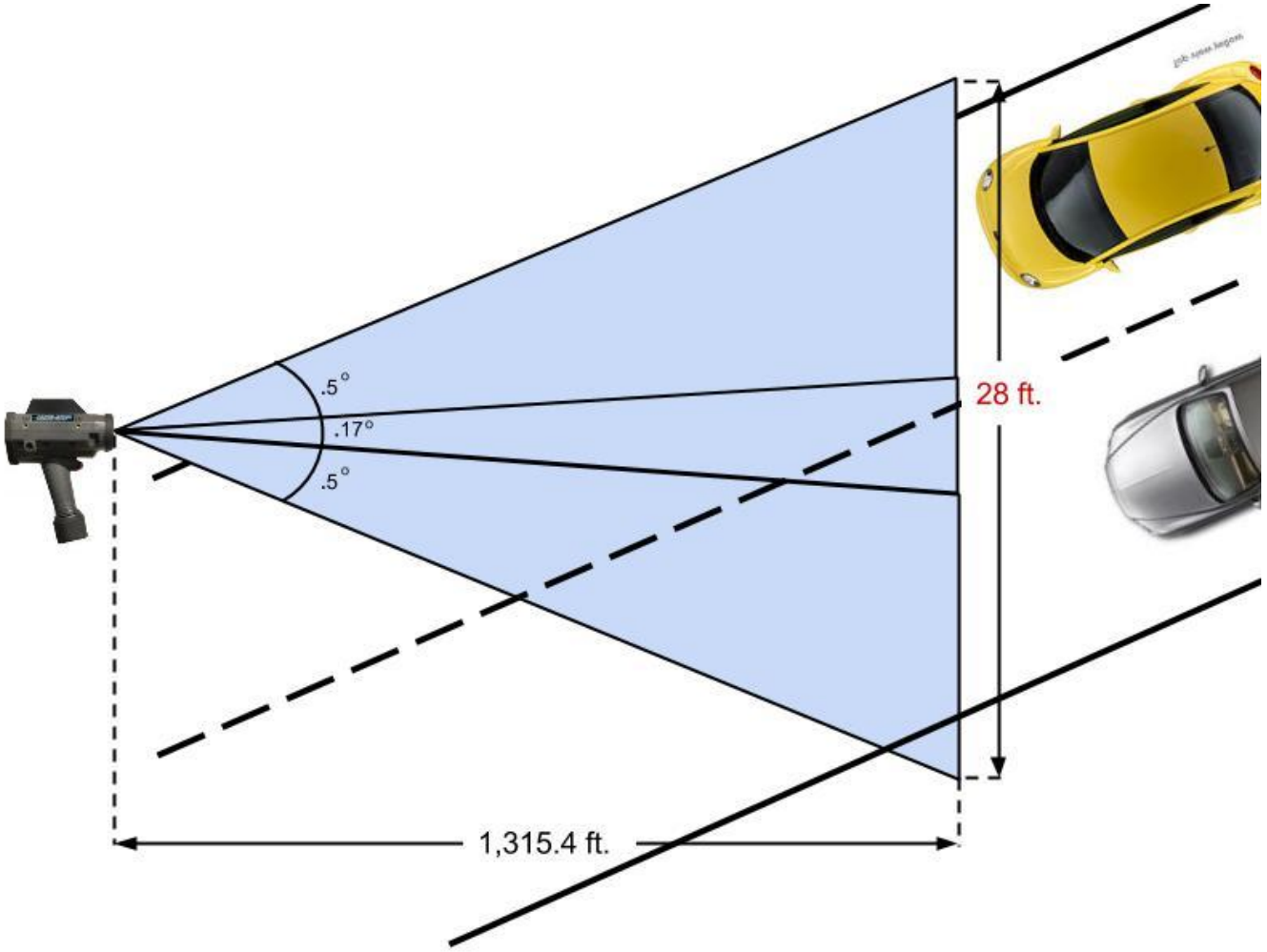
SEE REVERSE

- 4 lane highway, lane 2
- Daylight
- 71 MPH in a 55 zone
- Lidar at 1,315.4 feet
- (Convertible erroneously described as a coupe)

Beam spread assuming *perfect* aim



Beam spread assuming ½° of shake



What part(s) of car did beam bounce off?

- Officers trained to aim at reflective vertical surfaces
- Suppose officer aimed at headlight, but accidentally hit prominent sideview mirror, then swept to headlight

- Note that headlight is 6 feet from mirror

What could sweep do to speed reading?

- Gun “measures” speed for ~0.3s
- Suppose I was going the speed limit (55 MPH)
  - In 0.3s, car would go 55 MPH × 0.3s, or 24 feet
- Suppose a tiny hand motion caused laser beam to sweep from mirror to headlight
  - Would add 6 feet to the estimated distance
- Resulting speed reading: $\frac{24\text{ft.} + 6\text{ft.}}{0.3\text{s}}$ = 68 MPH
- I don’t claim this is precisely what happened
  - But it is roughly consistent with the ticket

IV. What do the experts say?

- Courts
- Legal scholars
- Technical experts
- The California Highway Patrol (CHP)
- Manufacturers
- Regulatory agencies

Seminal ruling on admissibility of Lidar

In re Admissibility of Motor Vehicle Speed Readings Produced by the LTI Marksman 20-20 Laser Speed Detection Sys., 314 N.J.Super. 233, 714 A.2d 381, 391-92 (1998)

"Admissibility of [Lidar] readings shall be subject to the rules set forth below:

Speed measurements made at any distance up to 1,000 feet shall be admitted, but **measurements made at any distance in excess of 1,000 feet shall be admitted only with the support of adequate expert testimony in the individual case**."

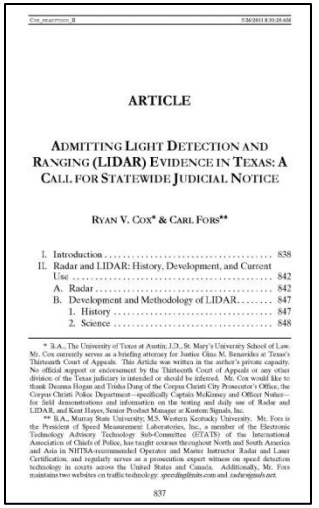
- This was 1998; have instruments improved?
  - Yes, but the laws of physics haven't changed

Recent St. Mary's Law Journal article *in favor of* judicial notice for Lidar evidence

Ryan V. Cox & Carl Fors, 42 St. Mary's L.J. 837 (2011)

"Generally, it is advised by most manufacturers that **an officer should not use laser readings past 1,000 feet for speeding infractions** because the laser's three-milliradian beam at 1,000 feet is thirty-six inches wide and, due to operator handshake, it is possible, though not probable, that part of the laser's beam might strike an adjacent vehicle."

- Newest guns have *wider* beams
  - TruSpeed S has a 3.5 milliradian beam
  - That's 17% larger
  - Beam covers 36% more area



ARTICLE

ADMITTING LIGHT DETECTION AND RANGING (LIDAR) EVIDENCE IN TEXAS: A CALL FOR STATEWIDE JUDICIAL NOTICE

RYAN V. COX* & CARL FORS**

* B.A., The University of Texas at Austin; J.D., St. Mary's University School of Law. Mr. Cox currently serves as a briefing attorney for Justice Gina M. Benavides at Texas's Thirteenth Court of Appeals. This Article was written in the author's private capacity. No official support or endorsement by the Thirteenth Court of Appeals or any other division of the Texas judiciary is intended or should be inferred. Mr. Cox would like to thank Deanna Hogan and Trisha Dang of the Corpus Christi City Prosecutor's Office, the Corpus Christi Police Department—specifically Captain McKinney and Officer Nuñez—for field demonstrations and information on the testing and daily use of Radar and LIDAR, and Kent Hayes, Senior Product Manager at Kustom Signals, Inc.

** B.A., Murray State University; M.S. Western Kentucky University. Mr. Fors is the President of Speed Measurement Laboratories, Inc., a member of the Electronic Technology Advisory Technology Sub-Committee (ETATS) of the International Association of Chiefs of Police, has taught courses throughout North and South America and Asia in NHTSA-recommended Operator and Master Instructor Radar and Laser Certification, and regularly serves as a prosecution expert witness on speed detection technology in courts across the United States and Canada. Additionally, Mr. Fors maintains two websites on traffic technology: speedingfirmly.com and radarguns.net.

Recent (Oct 2012) *Police and Security News* article reviewing new Lidar guns

"**If defense attorneys quote the New Jersey Superior Court ruling, a laser speed reading past 1,000 feet will not be accepted** on two grounds: It violates the 1,000 Foot Rule; and recognition distance is exceeded in establishing a Valid Visual Tracking History."

Carl Fors, President of Speed Measurement Laboratories Inc., has 28 years of experience in field-testing radar and laser devices. He serves many jurisdictions as an expert witness in radar and laser gun trials and teaches NHTSA standard Master Radar and Laser Instructor Certification courses at law enforcement agencies here and abroad.

Universal Rules:

If you're just out of the academy, don't complain. You haven't earned that right yet.

New Laser Speed Devices:

An Analysis of Performance and Features

Carl Fors, Speed Measurement Laboratories Inc.

"I've Got A Budget Of $18,000 For Laser Guns...What Should I Buy?"

CHP Lidar Operator Training Manual (2012)

"**Long-Range Acquisition –** Akin to a rifle, the lidar unit should not be used to acquire long range targets unless a stabilizing support is used. **Long-range target acquisition is <u>not</u> recommended** as it tends to make a proper tracking history more difficult to support."

"A laser beam emitted from a laser generator is very narrow in width and **will not spread significantly**."

"The narrow lidar beam width allows the instrument to operate with **pinpoint accuracy in selecting specific vehicles on a crowded roadway**."

"As with radar, the 'panning effect' may occur if the lidar unit is moved swiftly past a stationary object while transmitting. This may result in an error message."

Manufacturer's Claims

"**Ensures the accuracy of *every* speed measurement** before it even displays reading in the device. Accuracy validation is what makes all LTI lasers the most dependable speed device in the world, and why **they have *always* stood up in court**."

– *Laser Technology, Speed Enforcement/Measurement web page*

"An extremely narrow beam for **absolute target identification**."

– *Kustom Signals, ProLaser III Operator's Manual*

"Amazingly Accurate... **Easy speed detection and targeting** in single or multi-lane traffic, **regardless of traffic congestion**. **6000' Max Acquisition Range**."

– *Digital Ally, Laser Ally web page*

Stalker comes clean!

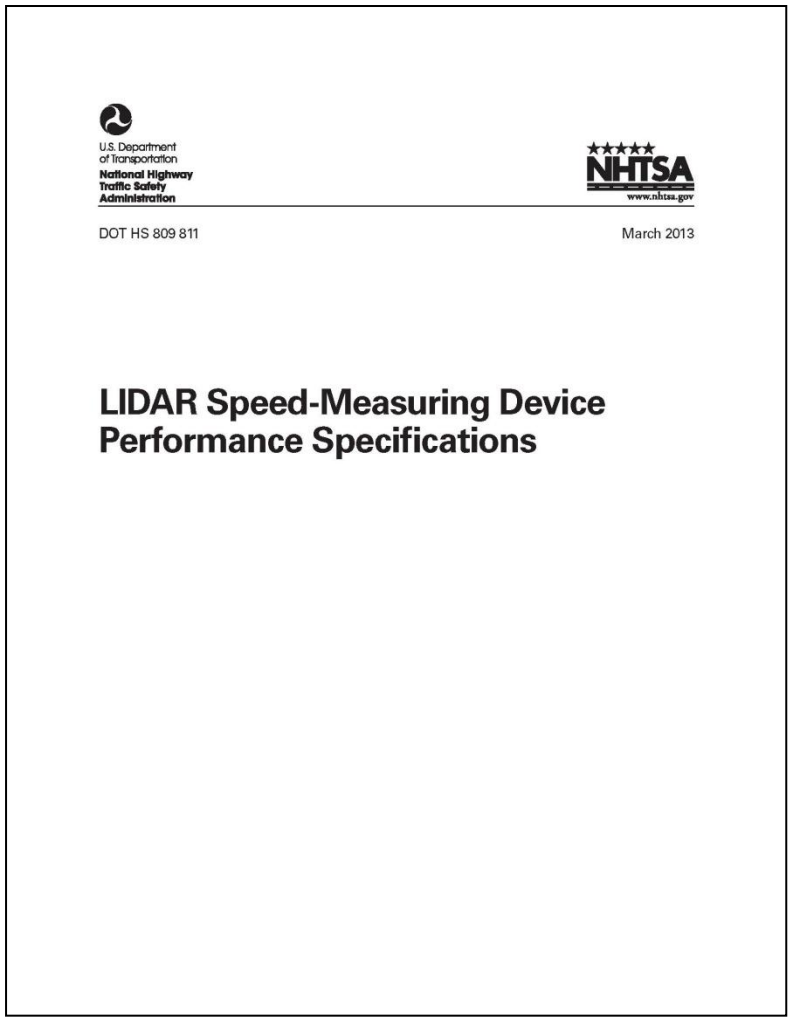
- Stalker Lidar manual (2008) discusses in depth
  - Statistical nature of “measurement”
  - Beam spread
  - Sweep effect
  - Importance of steady aim
- But they go to great lengths to keep manual away from the general public

Notice of Trade Secret. This Operator's Manual contains trade secret and protected information that is exempted from public and/or unauthorized disclosure under various state laws, federal laws, and the definition of trade secret under the Restatement of Torts.

Unauthorized or public disclosure of this Operator's Manual may cause substantial competitive injury or harm to Applied Concepts, Inc. APPLIED CONCEPTS, INC. SPECIFICALLY ASSERTS ALL OF ITS APPLICABLE PRIVILEGES AND EXCEPTIONS TO PROTECT ITS TRADE SECRETS AND PREVENT UNAUTHORIZED PUBLICATION AND DISCLOSURE OF THE OPERATOR'S MANUAL.

Standard of Care. You agree not use this Operator's Manual for any purpose other than in connection with police radar enforcement. You agree that the standard of care which you shall use in preventing disclosure of the Operator's Manual to third parties shall be at least the same care that you would take in preserving the confidentiality of your own sensitive information and classified documents. You also agree to exercise reasonable care in overseeing those with access to the Operator's Manual, and shall limit such access to only those of who have a need to know.

The NHTSA regulates Lidar guns



U.S. Department of Transportation
National Highway Traffic Safety Administration

NHTSA
www.nhtsa.gov

DOT HS 809 811

March 2013

LIDAR Speed-Measuring Device Performance Specifications

- Document specifies tests
- Testing labs certify Lidar guns
- IACP publishes list
- Police procure only listed guns

"NHTSA believes that these specifications and testing protocols will increase the confidence of the public, the courts, and law enforcement officers in the accuracy and reliability of this equipment."

Most of the required tests are performed on a "*Target Speed Simulator*"

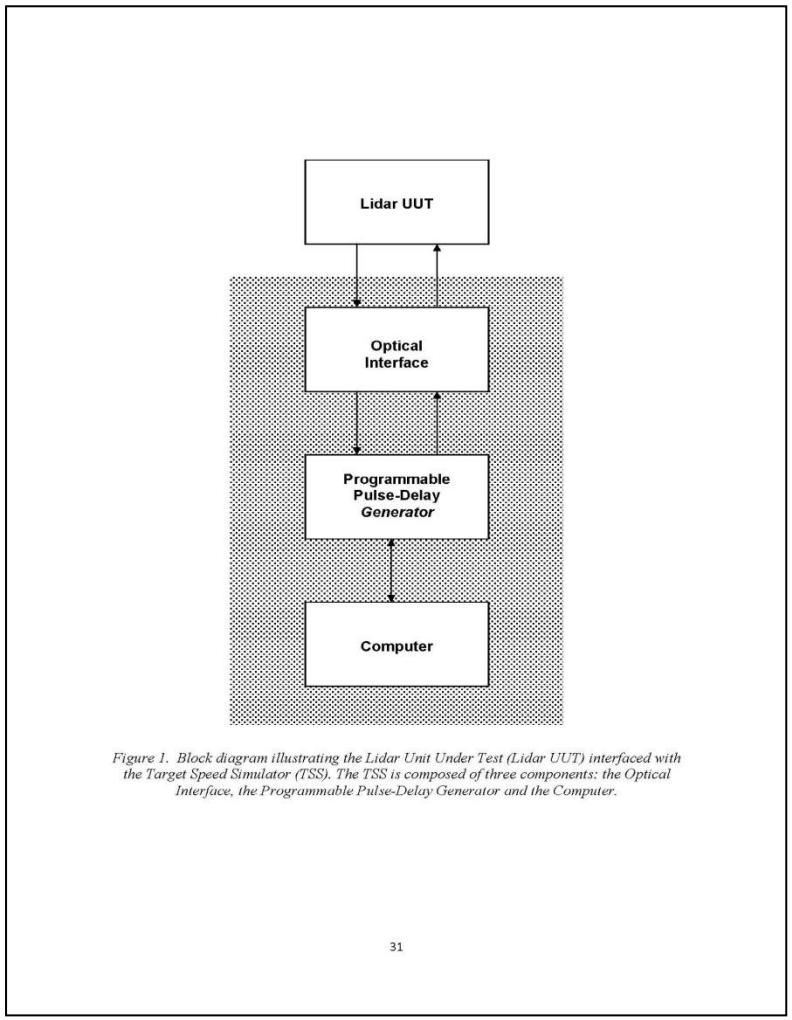


Figure 1. Block diagram illustrating the Lidar Unit Under Test (Lidar UUT) interfaced with the Target Speed Simulator (TSS). The TSS is composed of three components: the Optical Interface, the Programmable Pulse-Delay Generator and the Computer.

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- Lidar gun sits on lab bench
- Optically coupled to simulator with manufacturer-provided gear
  - Fiber optic cables permitted
- Simulator emits "return" pulses timed to simulate speed, distance
- Designed for ease of testing at the expense of realism
- Far-better-than-ideal conditions
  - Relevance to real world is unclear

Lidar Speed Measurement Simulator

The LTS hit obsolescence in the early 2000's when replacement parts were difficult to find. In 2004, the IACP contracted with Laser Technology, Inc. to design a replacement LTS. The LSMS was designed and 3 systems delivered to IACP. Since then many systems have been sold worldwide.

Key Points:

- Built for purpose system
- All timing and delays loaded internally
- Original Specification = 1 KHz max pulse rate
  - Has since been increased to 13 KHz
- Based on lidar units which operate using a fixed PRR
- Optical interface handles high pulse rates
- Includes a sweep test

  (simulates sweeping towards the lidar, 1.52 m (5 ft.) along a Smooth sheet-metal area in 0.178 s)

NHTSA Spec on the sweep effect

"***A LIDAR unit can potentially read an erroneous speed*** **if successive laser pulses are not all reflected from the same part of the same target vehicle**. **It is the *user's job* to hold the laser device steady**, but there is also a need for the instrument to reject bad data based on clues contained in the data set. That is, raw data of range versus time should ideally plot as a straight line; when the raw data deviate from straightness, the speed derived from the data is suspect, and it should not be displayed. The exact criteria for rejecting suspicious data have been a matter of engineering development and are proprietary to the LIDAR manufacturers. **This section will verify that the UUT has *some* ability to reject suspicious data.**"

NHTSA required “real world” (field) tests

- All tests can be performed on tripod
  - No assurance of accuracy of handheld reading
- Only three speeds are tested: 20, 50, 70 MPH
  - Speeds outside this range aren’t tested
  - Linearity within this range isn’t tested
- Test car drives at a constant speed
  - Accuracy when speeding up or slowing isn’t tested
- 1,000 feet suffices for range accuracy test
  - No assurance of accuracy at greater range
- These tests don’t cover real-world conditions!

An important omission in the spec

- Spec doesn’t prohibit firmware updates
- Some manufacturers issue them frequently
- New firmware can mean “new Lidar gun”
  - Key statistical algorithms can change
  - Gun used to write ticket may not have been certified

A possible conflict of interest

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Appreciation is also extended to the manufacturers of LIDAR speed-measuring devices for their cooperation in the preparation of this document.

- Standards bodies should represent all stakeholders
- Who is looking out for the motoring public?

Does the NHTSA spec satisfy its goal?

- “To increase the confidence of the public, the courts, and law enforcement officers in the accuracy and reliability of this equipment.”
- I know what I think, but you be the judge
  - I encourage you to read the spec for yourself

Conclusions

- Lidar guns are a valid speed enforcement tool
  - But they aren't infallible!
  - Wrong-car and wrong-speed errors do occur
- Error rates increase with distance from target
- New Jersey got it right in 1998
  - Readings from > 1,000 feet should be inadmissible
- The problem is not well publicized
  - Unbiased information is *very* hard to come by
  - I've provided an annotated bibliography

Recommendations

- **Lawyers and motorists:**
  - Contest Lidar tickets in excess of 1,000 feet
  - If you lose, consider an appeal
    - California needs case law
    - I'll be happy to provide pro bono assistance
- **Law enforcement personnel:**
  - Don't issue LIDAR tickets in excess of 1,000 feet
  - Don't let marketing influence your training materials

Recommendations (continued)

- **Lidar speed guns manufacturers:**
  - Don’t make misleading claims
  - Provide *much* more information on the web
    - At a minimum, complete specs and operator manuals
    - Ideally, service manuals and source code
- **Regulatory agencies:**
  - Vastly improve certification requirements
  - Consider requiring publication of all manuals
  - Optics matter: distance yourself from manufacturers

Postscript

“What about that ticket, Josh?”

- My attorney conferred with officer, who agreed to reduce the charge to a no-points violation
- We didn’t know anything about the judge, so I thought it wise to accept the settlement
- But the county ended up refunding my fine
  - The check said “exonerated” ☺

The Lowdown on Lidar

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